

Claims:

We claim:

1. An apparatus to transfer a gas to or from water comprising:
 - (a) a flexible planar element having an inner space for gas flow within the planar element and a gas permeable but liquid water impermeable membrane separating the inner space from the outside of the planar element;
 - (b) one or more conduits for transferring gas between the inner space and the atmosphere or another location outside of the inner space;
 - (c) one or more restraining members for holding the planar element in tension when installed in a reactor.
2. The apparatus of claim 1 wherein the planar element comprises a flexible spacer open to gas flow within the inner space.
3. The apparatus of claim 2 wherein the membrane encloses the inner space.
4. The apparatus of claim 1 wherein the one or more restraining members fix the planar element in a selected position in the reactor.
5. The apparatus of claim 4 wherein the one or more restraining members fix the planar member non-rigidly in a selected position in the reactor.
6. The apparatus of claim 1 wherein an inlet conduit and an outlet conduit are located at opposed sides of the planar element.
7. The apparatus of claim 6 wherein each of the inlet conduit and outlet conduit extend substantially along their respective opposed sides of the planar element.

8. The apparatus of claim 7 wherein the inlet conduit and outlet conduit are porous along a substantial portion of their length inside of the planar element.

9. The apparatus of claim 8 wherein the porous portion of the length inside of the planar element of at least one of the inlet conduit and outlet conduit is made of a section of the spacer or membrane.

10. The apparatus of claim 1 wherein the membrane is made of a textile substrate coated or impregnated with a non-porous, gas permeable, liquid water impermeable layer.

11. The apparatus of claim 1 wherein the membrane is made of a porous but hydrophobic material.

12. The apparatus of claim 11 wherein the layer is silicone rubber.

13. The apparatus of claim 1 further comprising a tube having a first end in fluid communication with the bottom of the planar element for withdrawing water from the inner space of the planar element.

14. The apparatus of claim 13 wherein the tube has a second end connected to a pump.

15. A reactor for transferring a gas to or from water comprising,

(a) a tank having an inlet and an outlet and a generally straight flow path covering a substantial portion of the tank between the inlet and outlet; and,

(b) a plurality of apparatus each having (i) a planar element with an oxygen permeable but liquid water impermeable membrane enclosing an inner space, and (ii) an inlet conduit having a first end in fluid

communication with the inner space and a second end extending out of the planar element,

wherein each planar element is restrained in a position in the reactor whereby the planar elements are generally parallel to the flow path.

16. The reactor of claim 15 wherein a plurality of planar elements are spaced in series along the flow path.

17. An apparatus to transfer a gas to or from a liquid comprising:

(a) a planar element having an oxygen permeable but liquid water impermeable membrane enclosing an inner space for gas flow within the planar element;

(b) one or more conduits each having a first end in fluid communication with the inner space and a second end extending out of the planar element;

(c) an upper mount for fixedly attaching the top of the planar element in a selected position in a reactor; and,

(f) a weight at the bottom of the planar element of sufficient weight to keep the planar element hanging substantially vertically downwards from the upper mount.

18. The apparatus of claim 17 wherein the planar element has an inlet conduit and an outlet conduit located at opposed sides of the planar element.

19. The apparatus of claim 18 wherein each of the inlet conduit and outlet conduit extend substantially along their respective opposed sides of the planar element.

20. The apparatus of claim 19 wherein the inlet conduit and outlet conduit are porous along a substantial portion of their length inside of the planar element.

21. The apparatus of claim 20 wherein the porous portion of the length inside of the planar element of at least one of the inlet conduit and outlet conduit is made of a rolled section of a spacer.
22. A module to transfer a gas to or from water in a reactor comprising,
 - (a) a manifold capable of being mounted above the liquid surface and carrying a supply of a first gas; and,
 - (b) a plurality of the apparatus of claim 17 each having an inlet conduit connected in fluid communication with the first gas in the manifold.
23. The apparatus of claim 17 wherein the membrane is made of a textile substrate coated or impregnated with a non-porous, gas permeable, liquid water impermeable layer.
24. The apparatus of claim 23 wherein the layer is silicone rubber.
25. The apparatus of claim 17 further comprising a tube having a first end in fluid communication with the bottom of the planar element for withdrawing water from the inner space of the planar element.
26. An apparatus to transfer a gas to or from water comprising:
 - (a) a flexible spacer;
 - (b) a flexible and gas permeable but liquid water impermeable membrane;
 - (c) an inlet conduit; and,
 - (d) an outlet conduit;

wherein,

 - (e) the spacer and membrane form a planar element with an inner space for gas flow within the planar element between the inlet conduit and the outlet conduit; and,
 - (f) the inlet conduit and outlet conduit are located at opposed sides of the planar element and extend substantially along their respective sides of the planar element.

27. The apparatus of claim 26 wherein the membrane is made of a textile substrate coated or impregnated with a non-porous, gas permeable, liquid water impermeable layer.

28. The apparatus of claim 26 further comprising a tube having a first end in fluid communication with the bottom of the planar element for withdrawing water from the inner space of the planar element.

29. A module to transfer a gas to or from water in a reactor comprising,

(a) a manifold capable of being mounted above the water surface and carrying a supply of a first gas; and,

(b) a plurality of an apparatus to transfer a gas to or from water comprising:

(i) a flexible planar element having an inner space for gas flow with the planar element and a gas permeable but liquid water impermeable membrane separating the inner space from the outside of the planar element; and,

(ii) one or more conduits for transferring gas between the inner space and the atmosphere or another location outside of the inner space;

wherein each apparatus is capable of being mounted below the water surface and each has an inlet conduit connected in fluid communication with the first gas in the manifold.